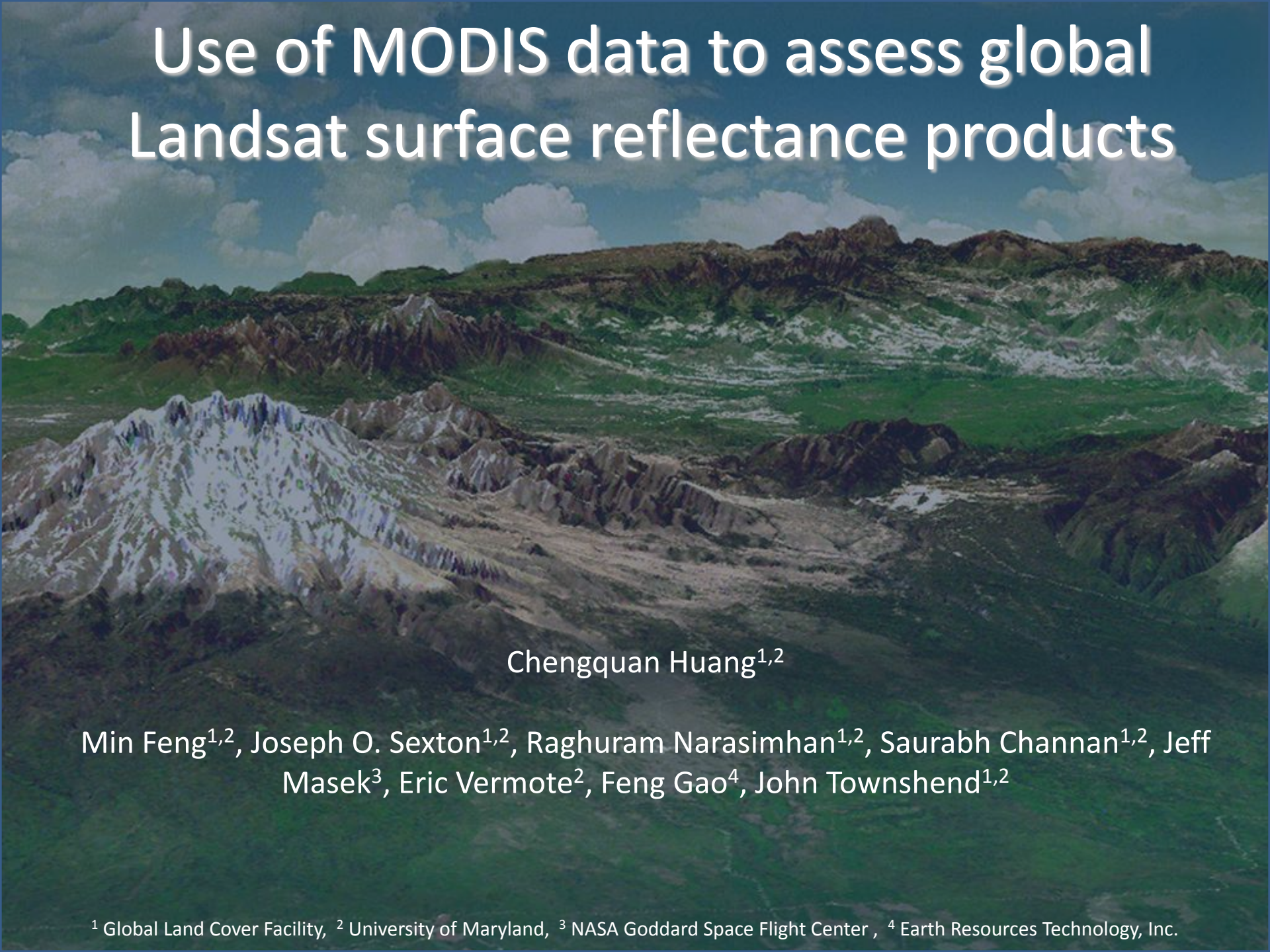
Use of MODIS data to assess global Landsat surface reflectance products



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Surface Reflectance as a Standard for Landsat

- Surface reflectance has been a standard for MODIS, providing:
  - More consistent imagery for mapping change
  - Improved cross-sensor algorithms using common radiometric basis (e.g. MODIS, Landsat)
  - Better integration with ground-measured reflectance (e.g. spectral endmembers) and canopy reflectance models to support biophysical products
- And soon will be for Landsat …
  - Landsat 8 and future missions
  - Historical Landsat SR data

Validation and Operational QA Necessary

- Validation using in situ data preferable
  - Limited to where and when in situ data are available
- QA of every Landsat image necessary
  - Many steps between data acquisition and SR generation
    - Sensor, transmission, media/transcription, calibration/correction, SR calculation
  - Errors could be introduced at each step
  - Each Landsat image generated independently, and therefore could have different types of errors
  - QA results of one image not extendable to another

Landsat-MODIS Comparison Provides an Operational QA Mechanism

- Landsat and MODIS SR are comparable
  - Have similar spectral bands
  - Similar orbits
    - Landsat 7 and Terra MODIS on the same orbit, with overpass only ~30 minutes apart
    - Near identical illumination and viewing geometry
    - MODIS daily data and Landsat 7 comparable
- Therefore a comparison is meaningful
  - If both are “correct”, they should agree with each other
    - They could also have good agreement if “wrong” in the same way, but rarely
  - Disagreement indicates problem in either one or both
- QA of all Landsat images during the MODIS era possible
  - MODIS data globally available, with better known quality
    - Evaluated comprehensively
    - Widely used at the global scale

Operational QA of First Global Landsat SR Products

- The Global Forest Cover Change (GFCC) project produces:
  - Global, Landsat resolution surface reflectance ESDR using GLS data sets
    - 2000 (8756 images)
    - 2005 (9015 images)
    - 1990 (7375 images)
    - 1975 (7592 images)
  - Global, Landsat resolution forest cover change (FCC) and fragmentation ESDRs
    - 1990-2000
    - 2000-2005
    - 1975-1990
  - Global 250-m vegetation continuous field (VCF) based FCC ESDR from 2000 to 2005

Overview of LEDAPS SR Algorithm

Based on MODIS/6S radiative transfer approach

- water vapor from NCEP (2.5deg) re-analysis data
- ozone from TOMS/EP-TOMS/TOVS/OMI
- topography-dependent Rayleigh correction

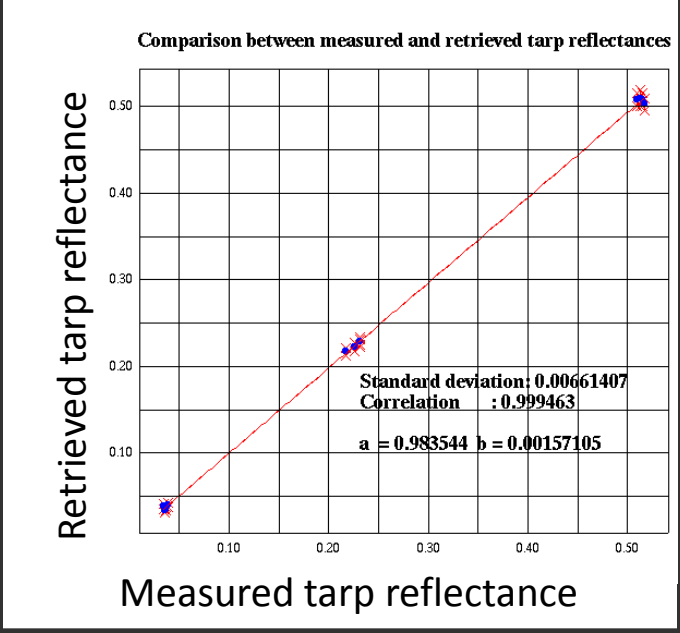
Aerosol optical thickness estimated from imagery using the Kaufmann et al (1997) "Dense, dark vegetation" approach

- Average Landsat TOA to 1km resolution; select "valid" targets for AOT
  - *NDVI > 0.3*
  - *2.2 mm TOA < 15%*
  - *screen for cloud, snow/ice, salt playas*
- estimate blue surface reflectance = 0.33*(2.2 μm TOA reflectance)
- difference between TOA_{blue} and SR_{blue} gives AOT_{blue}
- interpolate valid targets across image
- use continental aerosol model to calculate AOT spectrum

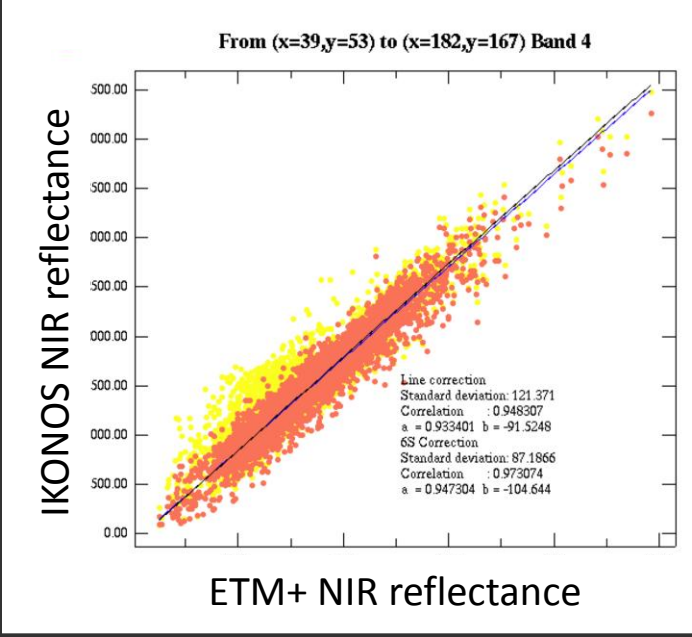
SR Validation using in situ Measurements

- Direct comparison with known targets
- Aeronet-based 6S vs. image-based 6S (Vermote et al.)
- Limited to where In situ measurements available

Comparison of 6S-corrected IKONOS vs laboratory-measured tarp reflectances, Stennis Space Center, Feb 15, 2002



Comparison of 6S-corrected Landsat vs IKONOS SR "truth", February 27, 2002



Aeronet-based 6S vs. image-based 6S

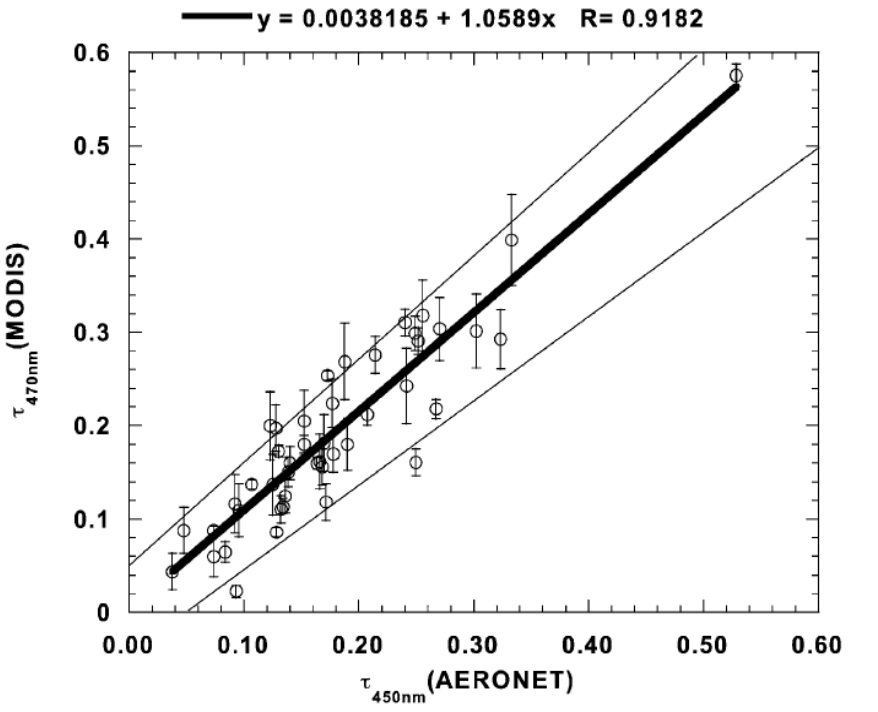
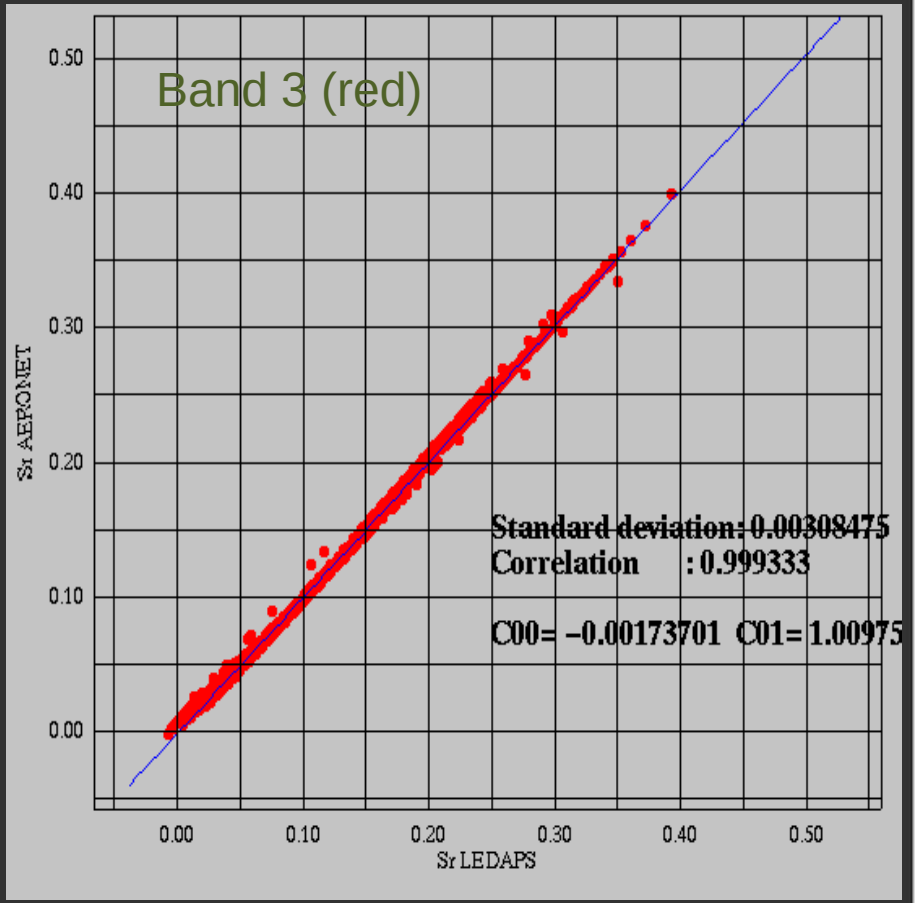


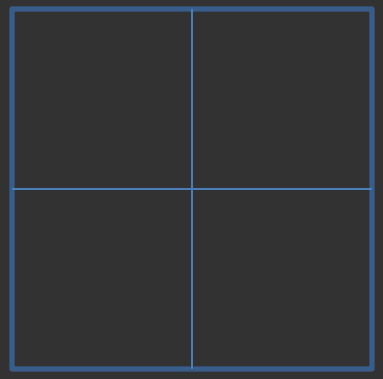
Fig. 1. Comparison of aerosol optical thickness retrieved by MODIS blue channel with AERONET Sun photometer measurements during the April 24, 2000 to June 10, 2000 period.



Validate aerosol retrieval → Validate SR

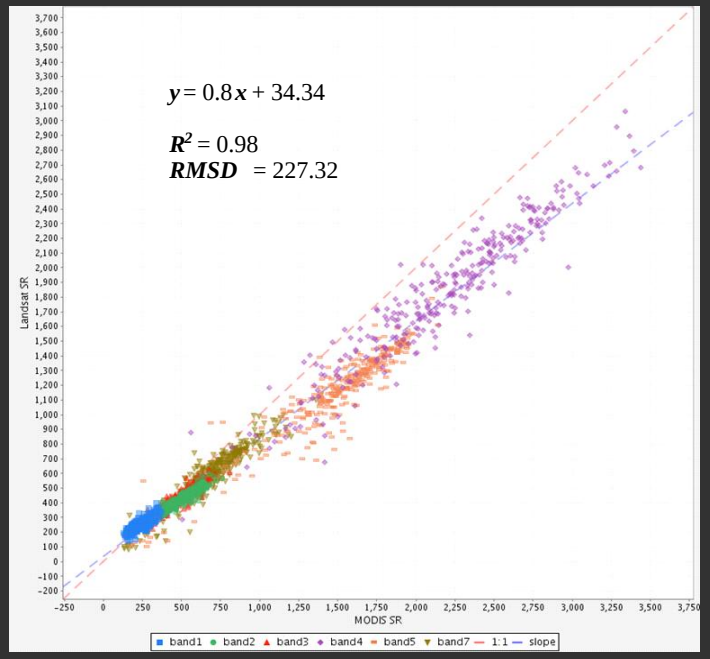
Landsat-MODIS Comparison – Approach Overview

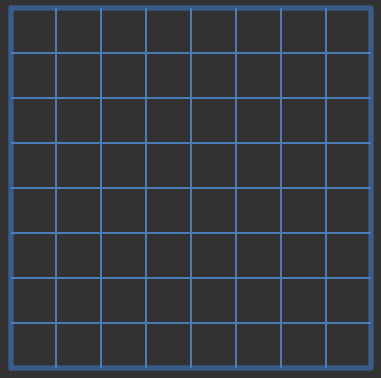
MODIS SR (500 m)



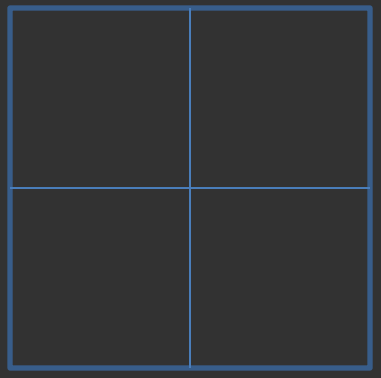
Use comparable samples:

- Homogeneous area
- No cloud





Spatial aggreg.

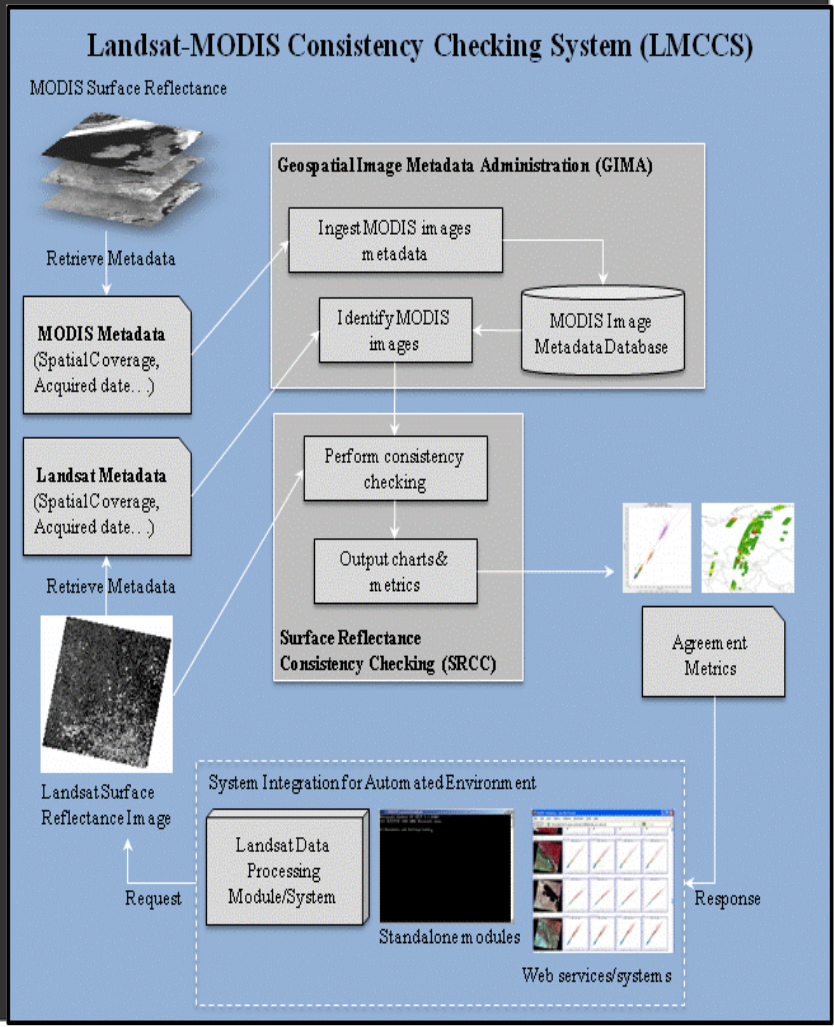


Landsat SR (30 m)

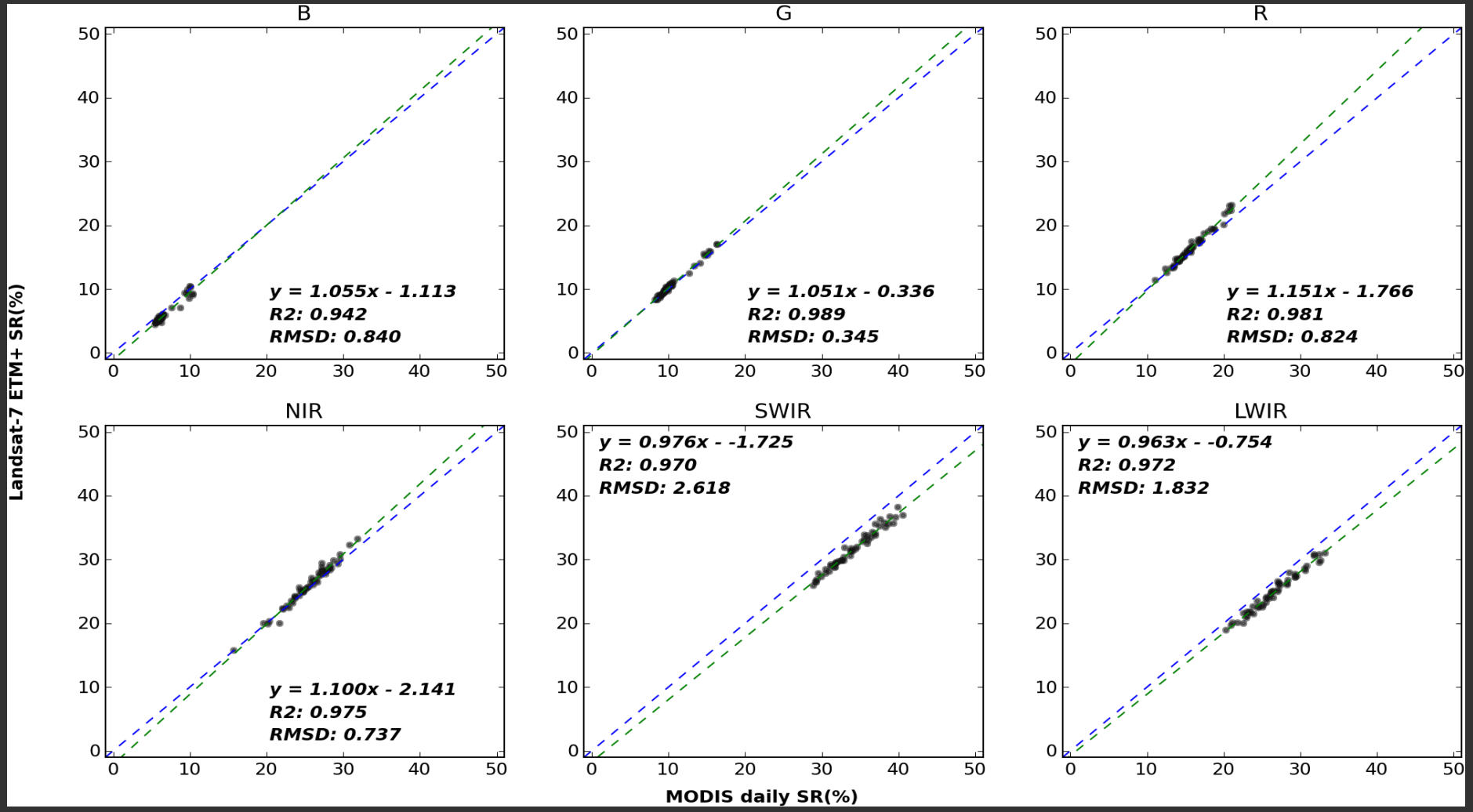
Landsat SR (500 m)

Automation through the Landsat-MODIS Consistency Checking System (LMCCS)

- Designed following Object-Oriented Programming (OOP) principles
  - Flexible for future expansion
- Developed using Java and open-source libraries
  - GeoTools, PostGIS, JFreeChart, Proj.4, etc.
- Support multiple platforms
  - Windows, Linux, Mac, etc.
- Run as a standalone system or a Java modules reusable in other systems.



Scatter Plots for One Landsat Image



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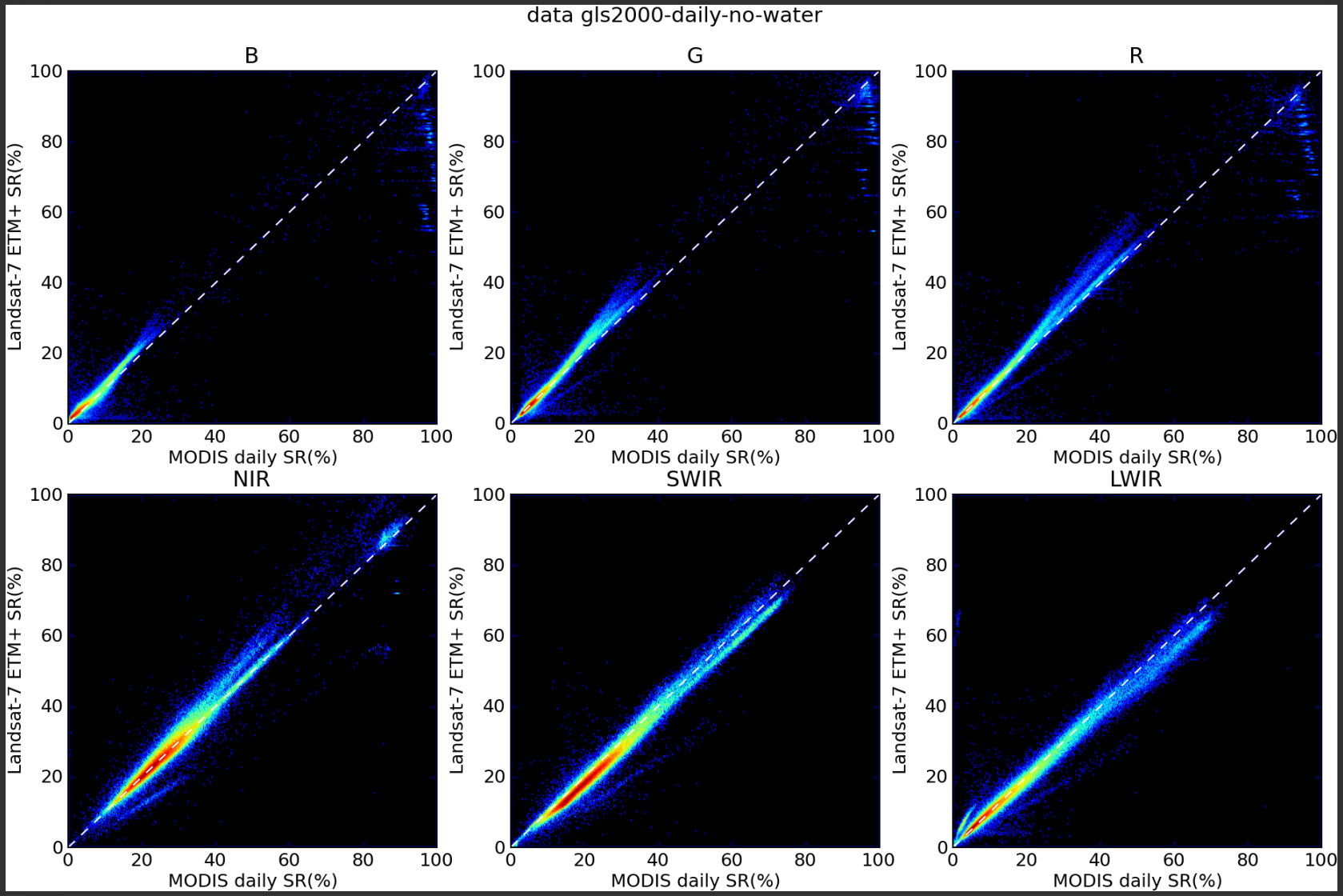
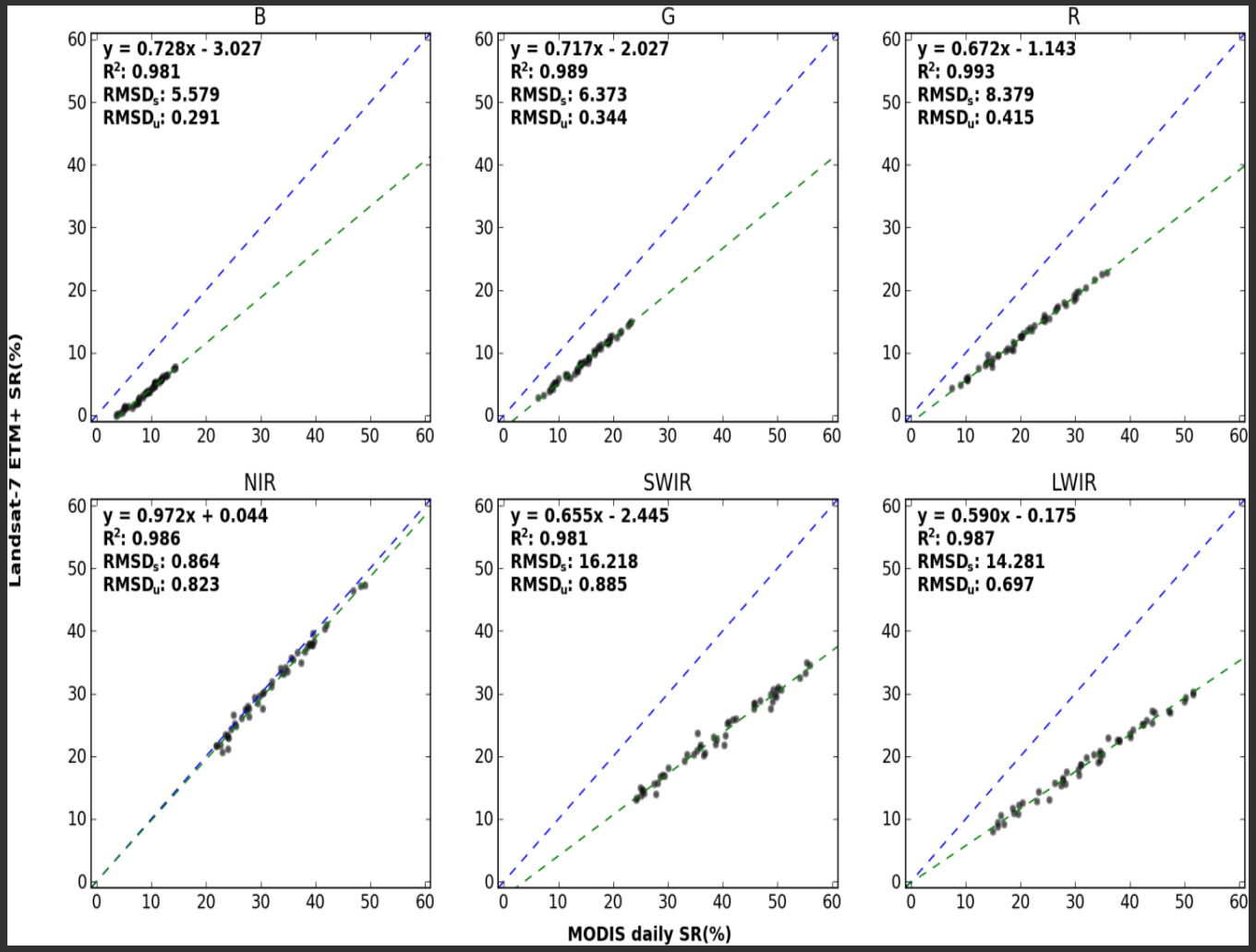
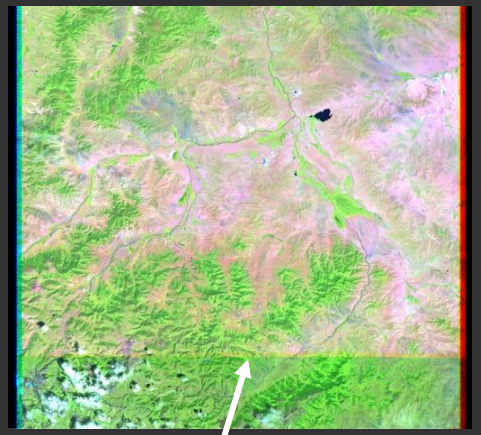
Scatter Plots for the Globe – GLS 2000 SR



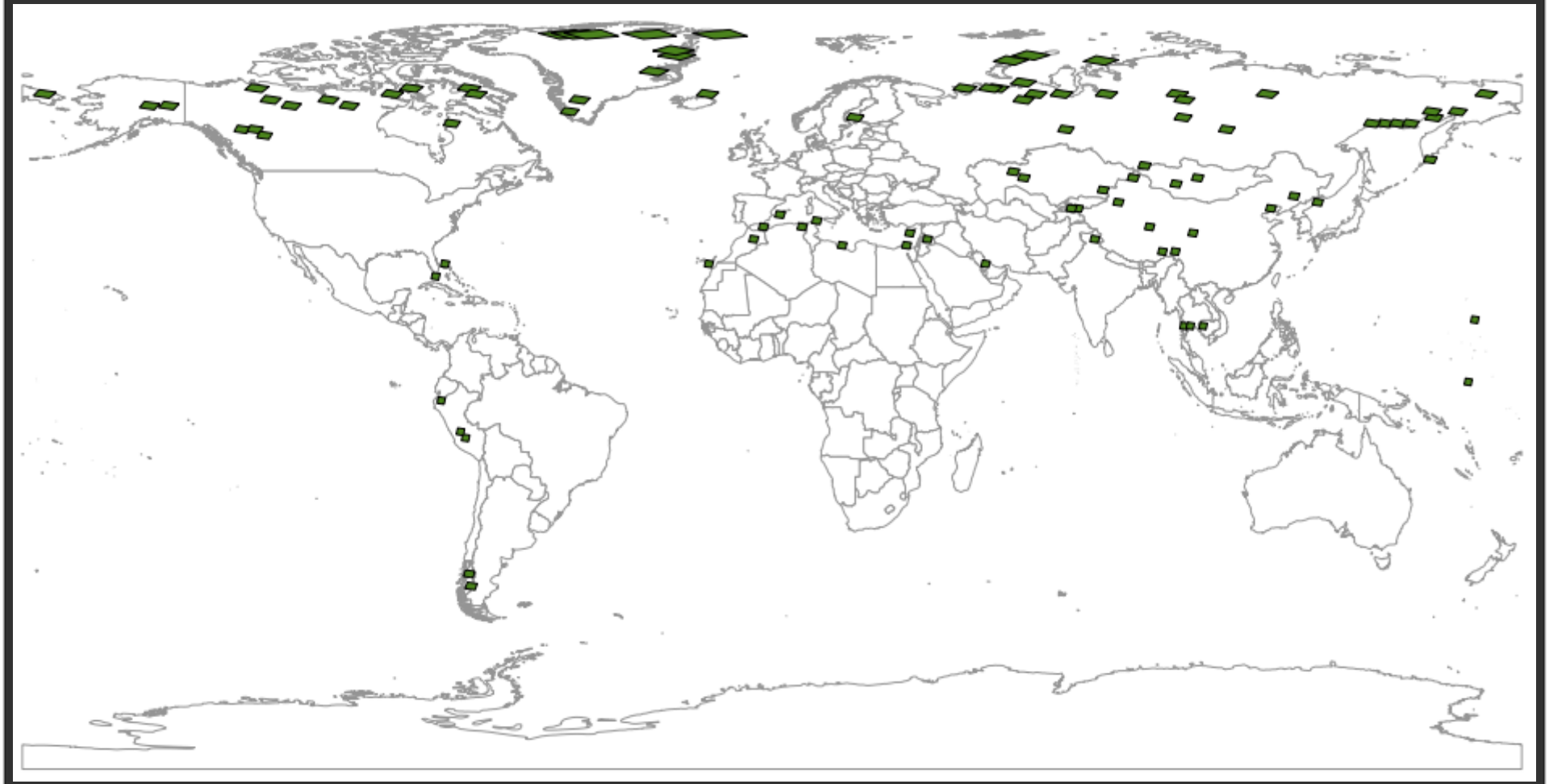
Systematic Biases between Landsat and MODIS SR



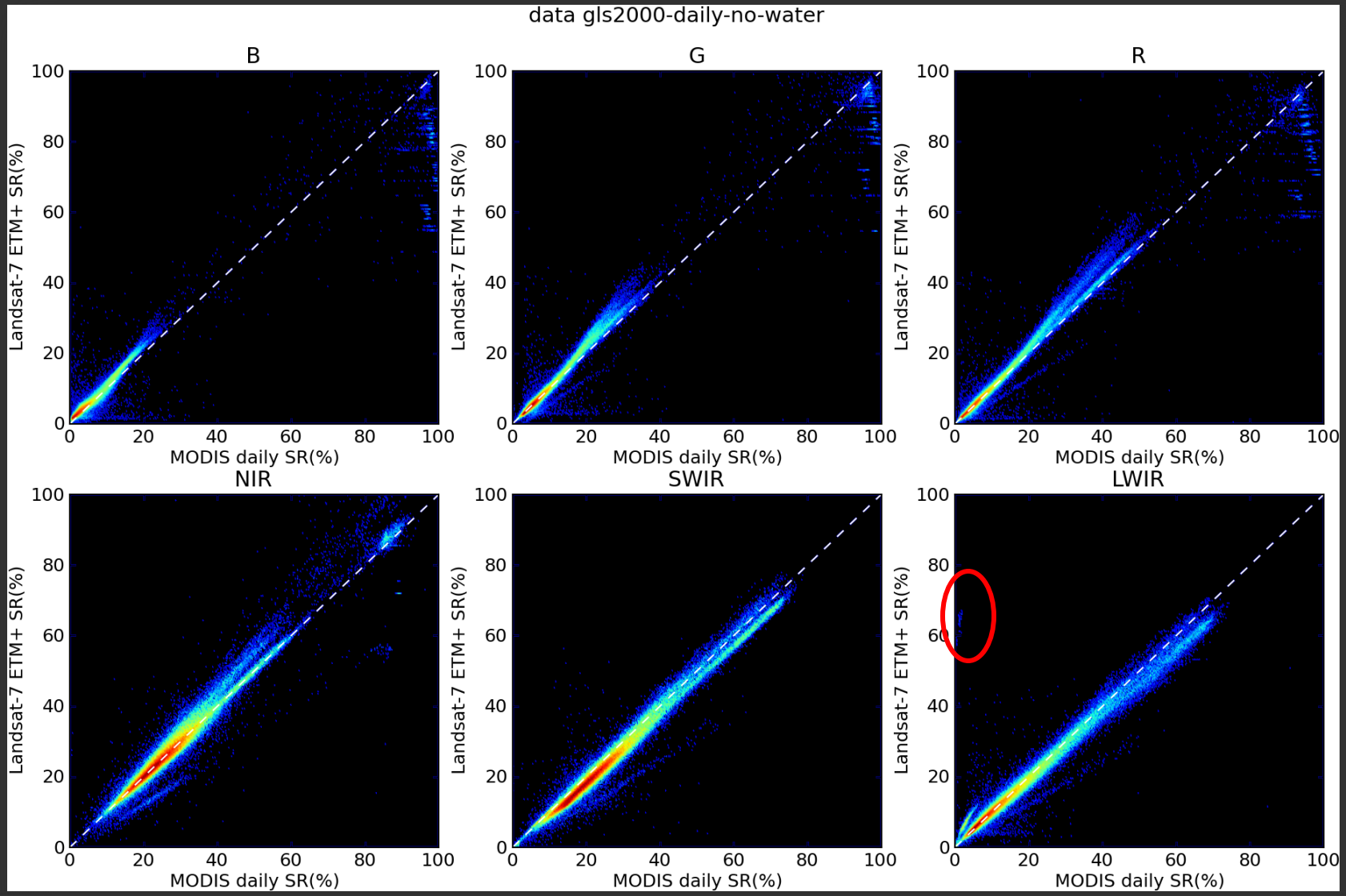


Sensor gain change

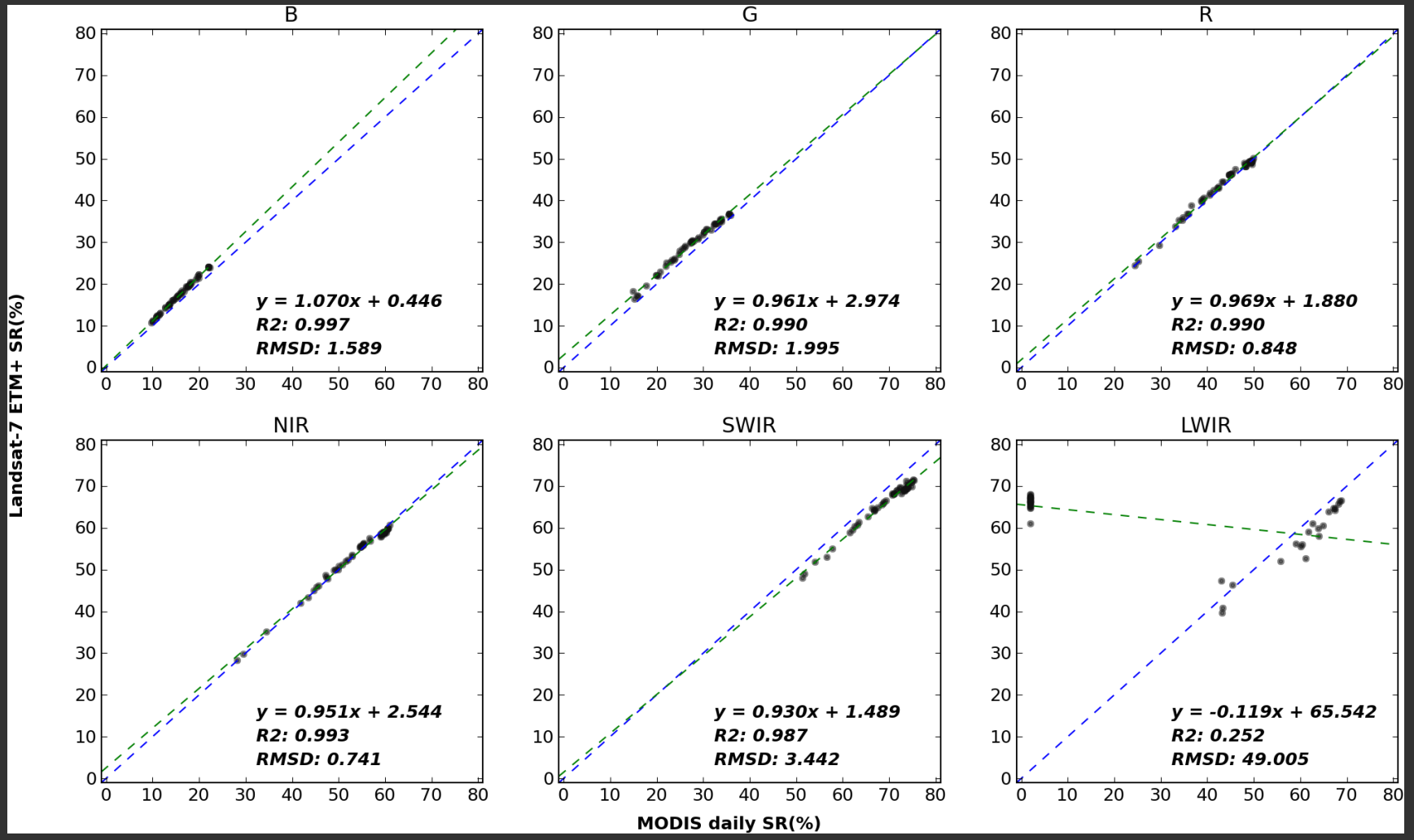
Distribution of GLS 2000 images with Possible Incorrect Rescaling Gain



Scatter Plots for the Globe – GLS 2000 SR

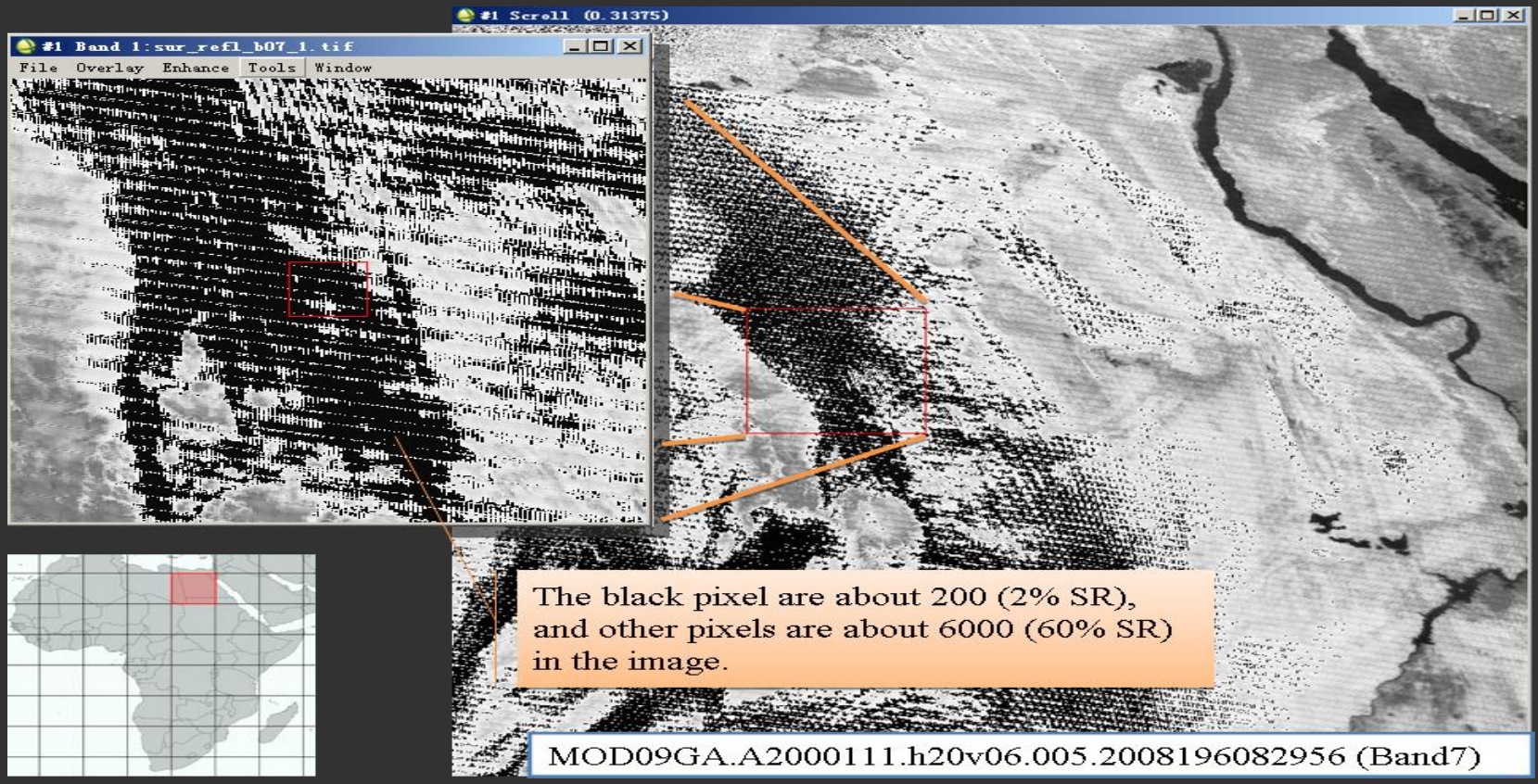


Scatter Plots for the Problematic Image



ETM+ image acquired on April 20, 2000 over Libya (WRS-2 path 181/row 43)

MODIS Data Not Free of Error



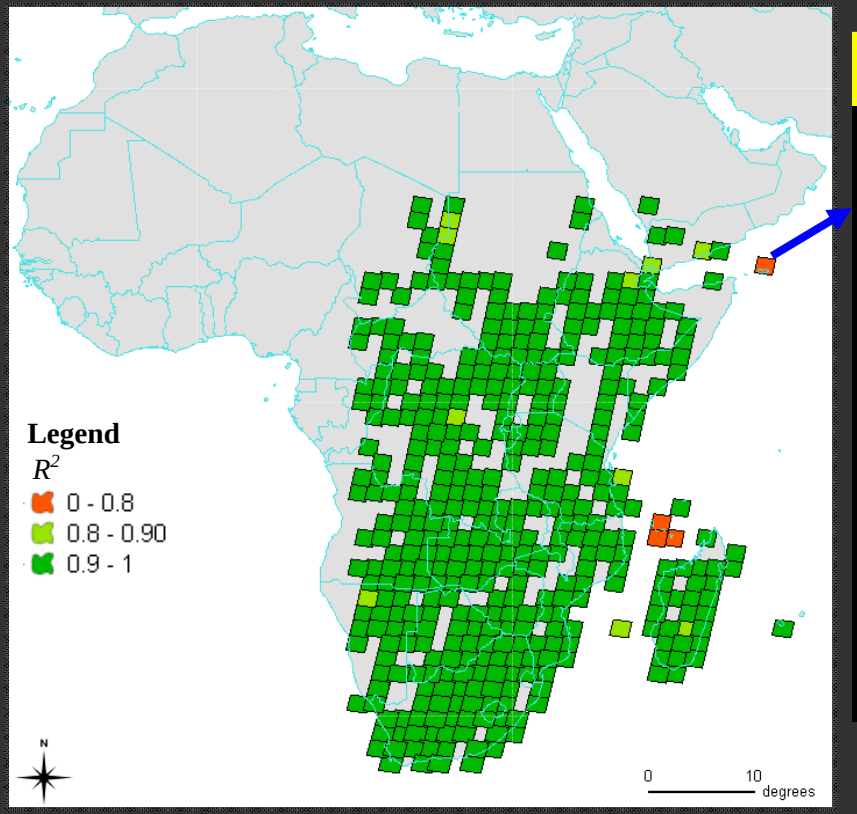
During the first few months after MODIS launch, the SWIR band was not set properly, causing saturation/overflow over very bright targets.

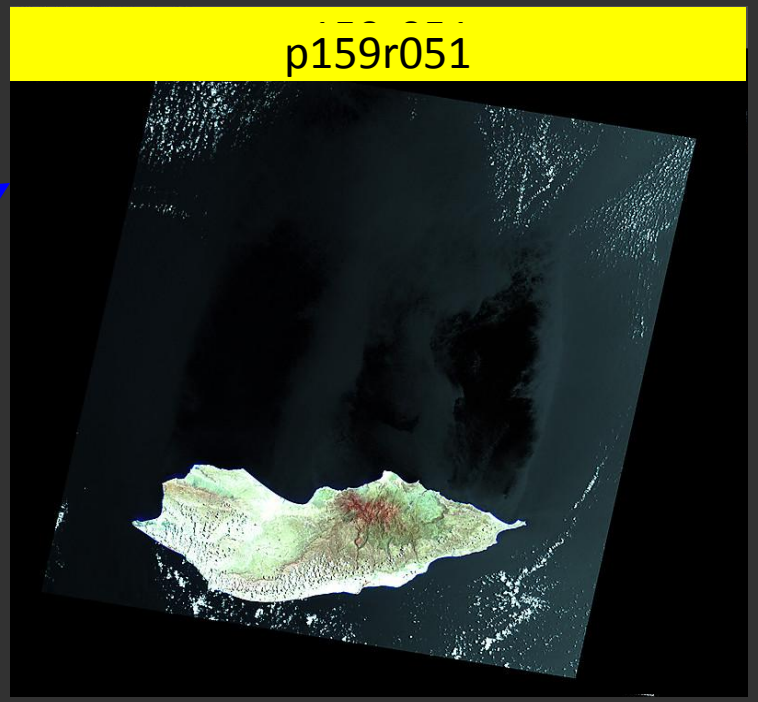
Landsat-MODIS Consistency Metrics

Algorithms	Consistency Metrics	Descriptions
Linear Regression Calculation	Slope (a)	The slope and offset indicate the linear regression trend between Landsat and MODIS. For close trend, slope ≈1 and offset ≈ 0.
	Offset (b)	
	R^2	Strength of the linear relationship between Landsat and MODIS SR. For a strong linear relationship, $R^2 \approx 1$.
Root-Mean-Squared Difference(RMSD) Calculation	RMSD $RMSD_S$ $RMSD_U$	Difference, accuracy, and precision of Landsat SR with respect to MODIS SR. Values ≈ 0 in each metric indicate close correspondence.
Mean Bias Error(MBE) Calculation	MBE	(Signed) bias of Landsat relative to MODIS SR. MBE ≈ 0 when bias is small.

Maps of Consistency Metrics Allow Global Evaluation

R^2 of Landsat-MODIS comparison





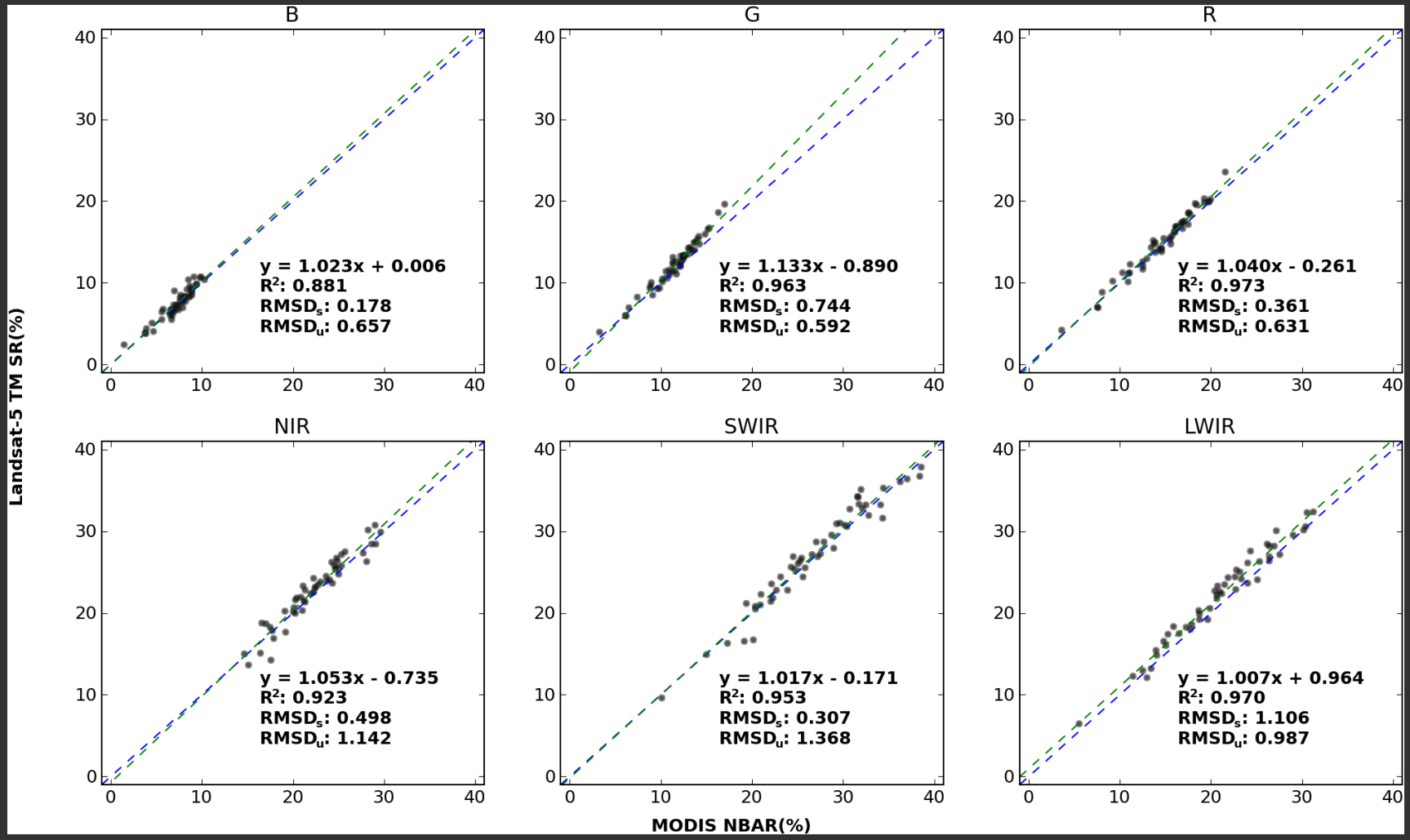
Conclusions from GLS 2000 SR QA

- Most Landsat images have good agreements with MODIS data
- Types of disagreements
  - Cloud moved between Landsat and MODIS overpass
  - Saturation in Landsat but not MODIS
  - Corrupted Landsat image
  - Problematic MODIS data
  - Possible incorrect rescaling gain in Landsat metadata

Is this Approach Applicable to Landsat 5

- Landsat 5 and MODIS orbits 8 days apart
  - Same day Landsat 5 and MODIS data exist, but have different illumination and viewing geometry
    - Disagreement from BRDF effect
  - Landsat 5 and MODIS data with similar illumination and viewing geometry are at least 8 days apart
    - Disagreement from changes that may occur in 8 days
    - Cloud conditions may be totally different
  - Can not use MODIS daily data. But comparison with MODIS NBAR meaningful
    - Illumination and viewing geometry normalized

Scatter Plots of TM-NBAR Comparison



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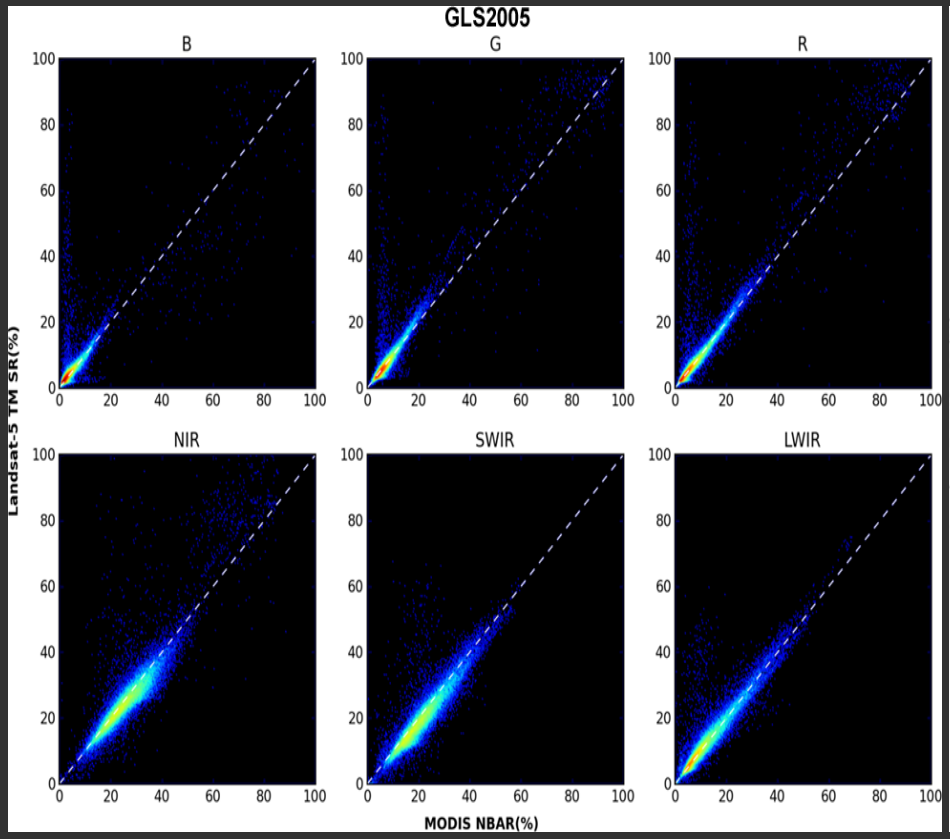
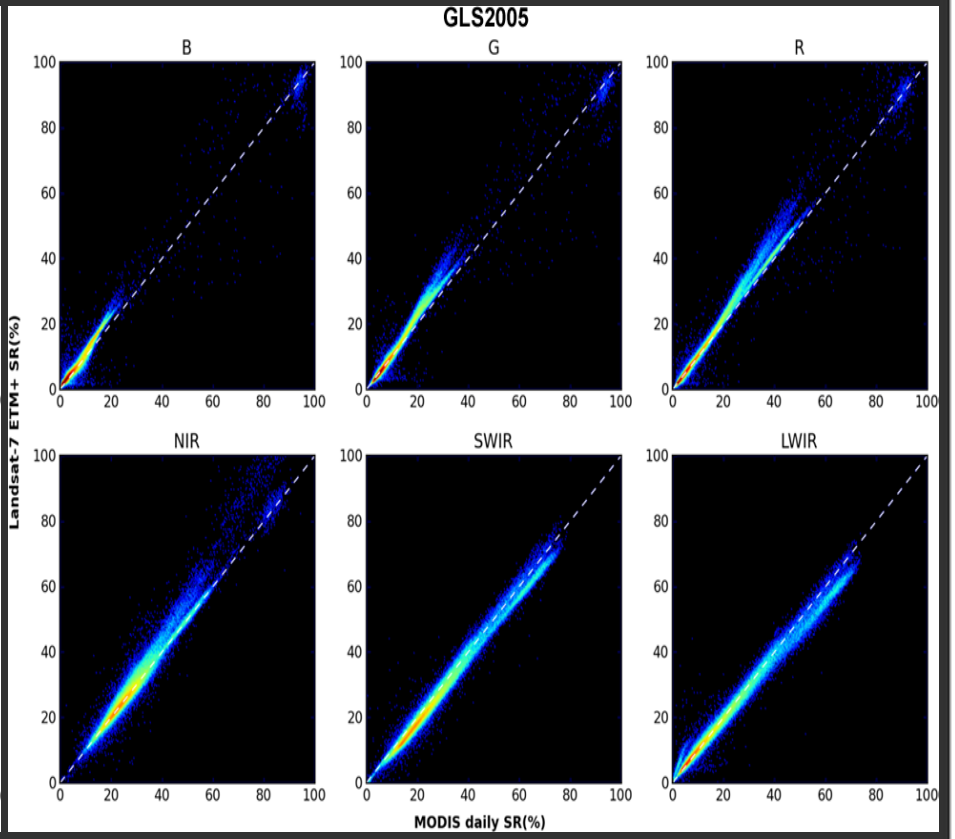
Operational QA of GLS 2005 SR



Comparison of Landsat 5 TM and MODIS NBAR



Comparison of Gap-filled ETM+ and MODIS Daily Data

Implications and Remaining Challenges

- Operational QA of Landsat SR feasible during the MODIS era
- For post-MODIS era, VIIRS or similar data sets may be used to replace MODIS data
- Further investigation needed for QA of pre-MODIS Landsat SR
  - AVHRR?
  - SPOT?